

*On the Spectrum of the Spontaneous Luminous Radiation of
Radium. Part III.—Radiation in Hydrogen.*

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As soon as we found* that the glow of radium bromide consisted mainly of light from nitrogen stimulated into luminosity by the radium, and giving the negative pole spectrum, we formed the intention of photographing the spectrum of the glow when the radium bromide was placed in an atmosphere of hydrogen, primarily in the hope of finding an answer to the question raised in our first paper, "Have we to do with occluded or with atmospheric nitrogen?"†, and, in the second place, to determine whether the radium is able to render hydrogen luminous.

In these experiments some unexpected results came out, which made it desirable to repeat them many times. This circumstance, together with the long exposures necessary—from 10 to 14 days—and the slow changes which we found to take place in the radium when allowed to remain in the hydrogen for long periods, reckoned in months, have necessarily delayed the publication of this paper. The investigation is still in progress, but it seems desirable not to delay any longer the publication of the results which have been already obtained.

An account of each experiment would make the paper long and unnecessarily tedious. It will be sufficient to give the results of each group of experiments made under similar conditions. The same form of apparatus was used for all the experiments. Small glass vessels were prepared consisting of a round cell with flat base, to hold the radium, into which, on opposite sides, tubes of small bore were blown, the walls of the cell were ground flat on the top to receive a thin microscopic cover-glass, or a thin plate of quartz, which was cemented down after the radium salt had been placed on an ebonite support within the cell.

As the glow of radium takes place at atmospheric pressure, it was desirable that experiments with hydrogen should be made under like conditions. A current of hydrogen was allowed to flow through the glass vessel for some minutes until all traces of air must have been carried out; the two tubes

* 'Roy. Soc. Proc.,' vol. 72, pp. 196 and 409.

† *Ibid.*, p. 199.

were then sealed up, leaving the radium in hydrogen at atmospheric pressure.

Afterwards, a second series of experiments was made with hydrogen at reduced pressure. The glass vessel was connected with a vacuum pump and exhausted to below 1 mm. of mercury; hydrogen was then allowed to enter. The vessel was again exhausted and refilled with hydrogen several times, and was then sealed up with the contained hydrogen at the pressure of about 1 mm. of mercury.

Portions of the same two specimens of radium bromide which had been used in our former experiments were employed, namely, one from Buchler & Co., Brunswick, and the other from the Société Centrale de Produits Chimiques, Paris.

The results of repeated experiments made in hydrogen at atmospheric, and also at reduced, pressure, and with both samples of radium bromide, were uniformly similar. The glow became sensibly fainter to the eye when the radium had remained for a few days in hydrogen; perhaps the diminution of the brightness took place sooner in hydrogen at reduced pressure. Photographic plates, exposed in the spectroscope to radium in hydrogen for the same time as to the same radium in air, showed a feebler spectrum, which was that of nitrogen without any traces of the lines of hydrogen.

From these experiments we may assume either the existence of occluded or combined nitrogen, or that the spectrum was due to minute traces of air which had remained within the vessel. If, however, the increasing feebleness of the glow was due to the latter cause, we should expect that on unsealing the tubes and admitting air, the glow would at once recover its original brightness. On April 15, 1904, when the radium had remained 26 days immersed in hydrogen, the tubes were opened and air blown through, but no recovery of brightness as estimated by the eye took place at the time. Then a photographic plate was exposed in the spectroscope for seven days, on which, when developed, the nitrogen spectrum was even feebler than on a similar plate which had been exposed for the same time before the air was admitted. A few days later, however, a small increase of brightness was detected by the eye, which continued until the radium slowly recovered its original brightness.

When radium was allowed to remain for months in an atmosphere of hydrogen some unlooked-for results were observed.

Experiment 1.—A portion of the Brunswick radium bromide was sealed up in hydrogen at reduced pressure on June 24, 1904.

(a) As in former experiments, the brightness of the radium bromide, as estimated by eye, gradually diminished.

(b) Photographs taken with the spectroscope showed the nitrogen spectrum only, and with increasing feebleness as time went on, until the strongest of the nitrogen bands only were just suspected upon the plate.

(c) Some days after sealing up in hydrogen, the radium bromide, which was originally of a yellowish-cream colour, began slowly to become darker, until by August 9, 1904, it had reached a dark russet brown.

(d) On March 17, 1905, the radium, which had now been sealed up for nearly eight months, was observed by eye to have become much brighter, indeed nearly as bright as the French radium which had remained in air. Unfortunately the radium in the hydrogen had slipped out of the ebonite support to the bottom of the cell, and, therefore, could not be brought before the slit of the spectroscope. It was then decided to open the vessel and remove the radium in order to photograph its spectrum while in this brighter condition. Before placing it in the spectroscope it was thought desirable to compare it again at night, about eight hours after it was taken out of hydrogen, with radium which had remained in air. To our great surprise the radium removed from the hydrogen had completely lost its light, it was now quite dark, without any sensible glow. It retained its very dark russet brown colour.

(e) Before the vessel was opened, while the radium was bright in hydrogen its radio-active power was measured with an electroscope; after it had been removed from the hydrogen and had become dark and glowless, its radio-activity was again measured. The amount of the induced leak of the charged leaves was found to be the same as before, showing that the sudden change from a bright condition to one without any sensible glow had not been accompanied by an alteration in the intensity of the β - and γ -rays.

(f) The glowless radium was examined in the dark at intervals of a few days. By May 9, 1905, a very faint glowing was perceived, and at the same time the dark brown colour was observed to have become less intense. These changes proceeded slowly until, by August 13, the radium had regained its original creamy colour and nearly its original brightness. During these three months its radiation, as measured by the electroscope, remained the same.

Experiment 2.—Fortunately we have for the purpose of comparison a portion of the French radium which has been sealed up in hydrogen at reduced pressure since September 12, 1904, about 11 months. Many photographs of the spectrum of this sealed-up radium have been taken at intervals from last September to the present time, showing, with similar exposures, increasing feebleness, but always, when any action could be detected upon the plate, some of the stronger bands of the nitrogen spectrum. Recently,

however, a band has appeared in the green part of the spectrum, for which the plate is but feebly sensitive, without any action being discernible on the plate in the blue and violet regions, for which the photographic film is greatly more sensitive. Fortunately on one plate the chief bands of the nitrogen spectrum, though excessively faint, can be just detected, while at the same time the new band, falling in a much less sensitive region photographically, is relatively strong.

The defined line which begins the band on the less refrangible side is a little more refrangible than the brighter edge of the green band of the Swan spectrum at λ 5165. The band has not yet been identified.

The band is accompanied by a faint continuous spectrum which runs back to D.

The radium bromide has turned to a dark russet brown colour, as in the former experiment. To the eye the brightness of the radium has remained greatly diminished, until within the last few days, when we suspect that, as in the preceding experiment, a slow increase of brightness has set in.

On re-examining all the photographs of the spectrum of the glow of radium which we have taken, a plate was found, developed on August 23, 1904, of the spectrum of a portion of the French radium which had been sealed up in hydrogen for a few days only, but when its light had faded to about one-half, which shows very faintly, but unmistakably, the new band.

The suggestion presents itself to the mind whether in both experiments when the radium had almost ceased to glow with nitrogen light, it was able to stimulate the molecules of the substance producing the band into luminescence. On this supposition an explanation of the sudden going out of the bright glow when the radium was taken out of the atmosphere of hydrogen in the first experiment would be found in the absence in the atmosphere of the needful molecules, the radium having lost temporarily the power of exciting nitrogen, unless we take the view that, to be stimulated into luminescence, nitrogen must be not merely in outward contact with the radium, but in a more intimate connection with it, which time is required to bring about.

The suggestion was considered in a former paper whether the operative cause of the glow was to be found in the β -rays, which are known to be analogous to the cathode corpuscles, upon the nitrogen of the air. In these recent experiments the electroscope showed that these rays, and the γ -rays, were being radiated with undiminished force at the time that the radium bromide remained glowless in air. It may be mentioned here that the cathode discharge is efficient in bringing out easily the first spectrum of

hydrogen,* but the radiations of radium appear to be unable to do this. Our experiments seem rather to support the view, suggested in our first paper, that the spontaneous light of radium may not be produced by any form of its radiations acting upon the nitrogen of the air outside it, but by a more direct action through encounters with nitrogen molecules, in some way associated with the radium, of those molecules of the radium which are undergoing active changes.

The Pressure of Explosions.—Experiments on Solid and Gaseous Explosives.

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(Abstract.)

Although this subject has been dealt with by numerous investigators, certain branches of it still remain practically untouched. With regard to the solid explosives used in ballistic work, the maximum pressure developed is usually well known, but the conditions which govern the combustion of the charge and the rate of cooling of the gaseous products require further investigation.

Explosive gaseous mixtures have only been studied at initial pressures but little above that of the atmosphere. Even in the case of coal-gas and air, which forms an exception to this rule, the work has not been extended to high pressures. The present research was undertaken with a view to filling in these gaps.

The first part of the paper describes the apparatus which was used for the investigation of both solid and gaseous explosives; the second part deals specially with the properties of cordite. The pressures are photographically recorded on a revolving cylinder by means of a specially constructed manometer. This manometer was designed with the object of securing the lowest possible time period.

The rise of pressure during the explosion of even the fastest cordite was, by means of this instrument, accurately inscribed without any oscillations being set up in the mechanism of the recorder. The pressures measured range from 100 to 1800 atmospheres (0·7 to 12 tons per square inch).

Many of the results obtained during the study of cordite are most easily

* Liveing, 'Proc. Camb. Phil. Soc.,' vol. 12, p. 337.